Programmable 1 Volt DC Voltage Standard

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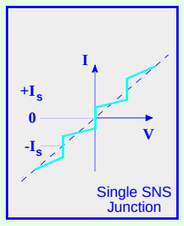
Introduction

We have developed a Josephson Voltage Standard (JVS) that produces intrinsically stable voltages that are programmable from **-1.1 V** to **+1.1 V.** The system uses a binary array sequence of 32 768 SNS (superconductor-normal-superconductor) jj's (Josephson junctions). The output can source or sink up to 2 mA, and thus has high noise immunity.

SNS Josephson Junctions

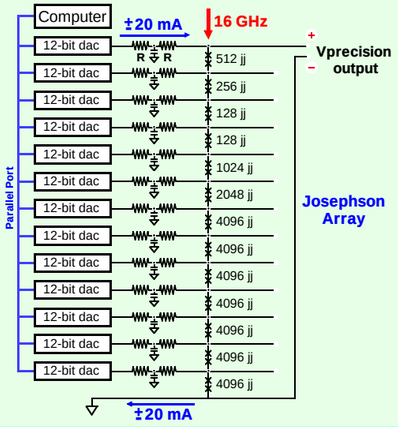


This is the I-V characteristic of a SNS Josephson junction (jj) when RF energy is applied (*f* = 16 GHz). At bias currents +Is and -Is, the jj produces constant-voltage steps that are precisely *V = f / Kj*. (The constant *Kj* is 483 597.9 GHz/Volt.)

At 16 GHz, the voltage produced by each SNS jj is on the order of 33μV.

The 1-Volt programmable JVS consists of 32 768 SNS jj's connected in series, and subdivided into smaller groups that are independently turned on and off. The JVS output is the sum of the voltages produced by all of the segments, and is given by the equation ***V = N f / Kj***, where *N* is the step number for the entire array, (i.e. the number of jj's turned on.) The JVS functions as a 9-bit (including sign) digital - to - analog converter, where every output level is known with Josephson accuracy.

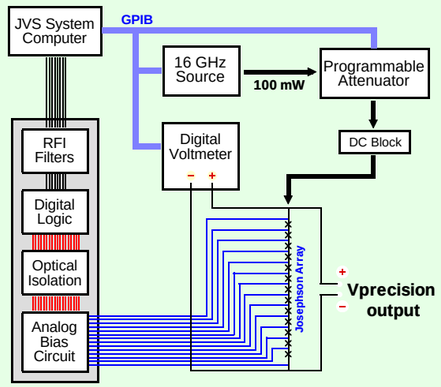
Bias Circuit Schematic



Bias Electronics

The individual segments of the SNS array are set to the **+1, 0,** or **-1** state by 12-bit voltage-mode DACs that are controlled via the parallel port of the system PC. The computer controls the JVS output by programming the step number *N*, and the RF drive frequency *f*. The PC loads the 12-bit DACs in about 500μs, and then triggers them to update simultaneously. The JVS settles to the new precision level in a few microseconds.

System Block Diagram



System Overview

The programmable JVS is fully automated. An ordinary PC computer controls all components of the system, and automatically measures operating parameters, confirms functionality, and verifies that the output voltage steps are flat (over a +2 to -2 mA current range) with sub-micro-ohm precision. For some operations, the PC monitors the JVS output directly using a DVM that it connects via relays. The analog bias circuitry is battery powered, and optically isolated from the digital electronics.

Applications

The rapid programmability, inherent output stability, and high noise immunity of this JVS make it superior to a conventional JVS for many dc measurements. (We define a dc measurement to be one in which the transient associated with changing the step number *N* can be excluded from the measurement). Some of these applications include:

- Fast characterization of D/A and A/D converters.
- Comparison against conventional SIS voltage standards and Zener references using null voltages of 1μV or less.
- Providing a stable, reversible, precision voltage reference for experiments like the Watt Balance.
- Precise characterization of capacitors used in electron counting experiments.
- Measurement of the *Thermoelectric Transfer Difference* of Thermal Voltage Converters using the FRDC (Fast Reversed DC) Method.
- A special, low voltage, high resolution version of the device has been proposed as the voltage leg in a metrology triangle experiment.

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